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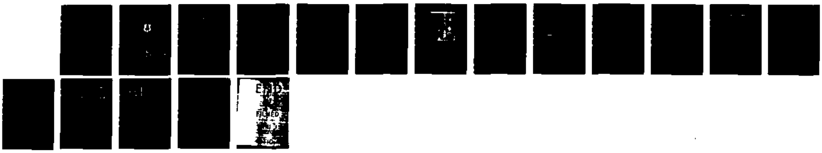

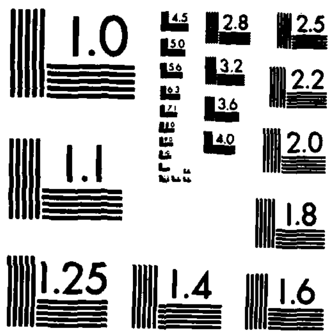

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ORBITAL STATIONS: A TIME OF QUESTS
AND ACCOMPLISHMENTS

by

A. Gorokhov

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О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

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Orbital Stations: A Time of Quests and Accomplishments

A. Gorokhov, engineer.

On 23 April 1971, after having been launched on the "Soyuz-10", the cosmonaut-pilots of the USSR, V. Shatalov, A. Yeliseyev and N. Rukavishnikov took a new step on the way to long-term orbital stations. Their flight program included the testing of new rendezvous and docking systems for spacecraft and for combined experiments with the "Salyut" scientific laboratory.

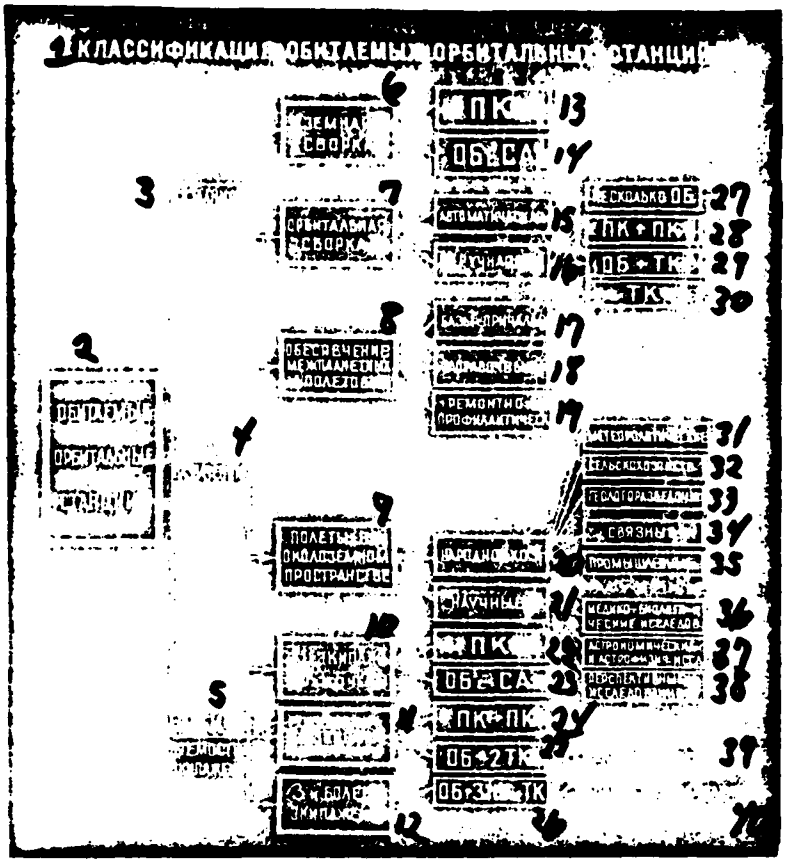
This article tells what long-term orbital stations are, and what kinds of prospects they are opening up for space researchers.

The space decade, which has just passed, has shown: space can serve people in the most diverse terrestrial matters, whatever they are. Right at the present time the crews of spaceships and automatic vehicles are supplying valuable information about the weather, about the snow cover on the continents, and about the geography of the "white spots" of our planet. But no matter how many ships and vehicles are launched, the scientific investigations, conducted on them, are limited by very rigid constraints. These constraints are the insignificant duration of the flights of spacecraft and the limited nature of the arsenal of the scientific means on the automatic space vehicles. Certainly, nobody intends to write off as scrap the spaceships and the automatic satellites, which have been tested and flown in space. They will still be serving science for a long time. But the solution of the key problems of cosmonautics requires the creation of long-term scien-

laboratories in near-earth orbits, with an operational time of several months, and even of years. Long-term orbital stations are a new qualitative stage of cosmonautics. These stations make it possible to conduct basic research in space. From a space station it is possible to monitor the state of the soil and of crops and to forewarn agricultural workers about the appearance of pests and to detect forest fires. From orbit sailors obtain systematic information about currents, the state of the seas, and about ice conditions and storms. From a space station it is possible to carry out searches for deposits of natural resources and to notify and warn about the occurrence of earthquakes and the eruptions of volcanoes. Civil Aviation aircraft navigators take advantage of the services of cosmonauts. With the appearance of long-term orbital stations scientists will have at their disposal unique laboratories for systematic astronomical, astrophysical, and bio-med research, and for experiments connected with the further mastery of space. Engineers will be able to have sufficient time to carry out the most important operations in space: the rescue of cosmonauts, launching from orbit, and the refueling and repairing of spacecraft.

With time orbital stations will become industrial enterprises to a certain degree. The vacuum and weightlessness promise exceptional conditions to the technologists. A liquid takes the form of an ideal sphere; space is an ideal shop for the manufacture, for example, of balls for bearings. In weightlessness it is possible to blow hollow structures of any shapes. Metallic and ceramic articles will be manufactured without containers for melting and crystallization. Certainly, at first this production will be expensive, but shuttle transport craft will make space technology a completely profitable matter.

The crews of orbital stations will learn to carry out assembly and do repair work in open space, and transport cargo, etc. The equipment, located on-board the stations will help the space assemblers. In one case this is a platform, and in another it is an airtight cabin. The devices will be equipped with motors, with an oxygen supply, power supply sources and remotely controlled holders. Radar devices will help the space "truck" rendezvous with the required object.



On the block diagram: PK - manned spacecraft; OB - orbital unit; SA - descent vehicle; TK - transport vehicle.

KEY: 1 - Classification of manned orbital stations; 2 - Manned orbital stations; 3 - By method of creation; 4 - By purpose; 5 - By exchangeability of crews; 6 - Ground assembly; 7 - Orbital assembly; 8 - Supporting interplanetary flights; 9 - Flights in near-earth space; 10 - 1 crew/3-6 men; 11 - 2 crews; 12 - 3 and more crews; 13 - PK; 14 - OB with SA; 15 - Automatic; 16 - Manual; 17 - Mooring bases; 18 - Servicing (refueling); 19 - Repair-Maintenance; 20 - National-Economy; 21 - Scientific; 22 - PK; 23 - OB with SA; 24 - PK+PK; 25 - OB+2TK; 26 - OB+3 and more TK; 27 - several OB; 28 - PK+PK; 29 - OB+TK; 30 - TK; 31 - Meteorological; 32 - Agricultural; 33 - Geological-Survey; 34 - Communications; 35 - Industrial; 36 - Bio-Med Research; 37 - Astronomical and Astrophysical Research; 38 - Long-Term Advanced Research; 39 - 1 replacement of crews; 40 - 2 and more replacements of crews.

The crews of orbital stations will become proficient in many space professions. But this is in the future. But today engineers are doing the research. And the attention, which they are devoting to near-earth laboratories, is the best guarantee, that the dreams of the founders of cosmonautics will find their realization in metal.

"An Ethereal Settlement Near the Earth..."

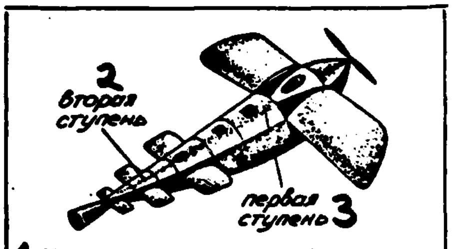
"It seems to me, that the first seeds of thought in this vein were planted by the famous visionary, Jules Verne: he aroused the working of my brain in this particular direction. Desires arose and the activity of the mind developed as a result of these desires... The motion around the Earth of vehicles, with all the accessories for the existence ofintellegent beings, can serve as a base for the further propagation of mankind." These lines from the second edition (1911) of the classical work by K. E. Tsiolkovskiy, "The Investigation of Outer Space with Reactive Devices", give a very accurate definition of an orbital station - a base, a spaceship, permanently located in near-earth orbit, equipped with everything necessary for the prolonged sojourn of a crew in space.

Tsiolkovskiy was not alone in his quests. In France in 1913 there appeared the work of the well-known aviator, Robert Esnault-Pelterie, on rocket flights. Seven years later a professor at Clark College in Massachusetts, Robert Goddard, published the brochure, " A Method of Reaching Extreme Altitudes." In 1923 in Munich the work, "Die Rackete zu den Planetenraeumen"("The Rocket into Planetary Space"), was published by Hermann Oberth. The German scientist allotted considerable attention to interplanetary stations and their possible purposes.

Everything that was written by these authors was, in principle, a repetition of the works of Tsiolkovskiy. Oberth himself wrote to Konstantin Eduarovich in October 1929: "I, certainly, would be the very last person, who would dispute Your precedence and Your contributions with respect to rocket matters... Today, in my own works, I would, certainly, be much farther ahead and I would have avoided much useless work, if I had known about Your excellent works earlier in time."

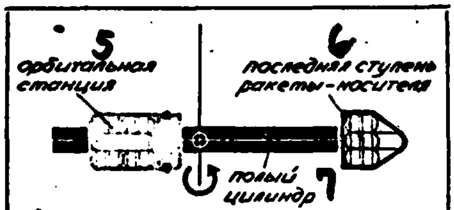
In 1929 there appeared one of the first plans for a space station, which had been carefully worked out with respect to design. Its author was the Austrian Potochnik, known under the name of Hermann Noordung. The station consisted of three parts: the "habitable wheel", the "laboratory", and the "machine compartment", connected with each other by cables and air hoses. Noordung positioned the cabins for the crew in

the rim of a thirty-meter wheel, which should rotate around its axis, in order to create a similitude to gravitation. The "laboratory" was in the form of a cylinder. At the focal point of a large concave mirror, mounted in the "machine compartment", Noordung proposed installing steam pipes. The steam produced would drive turbines, connected with a generator. Thus, Noordung had resolved the problems of an energy supply for the station.



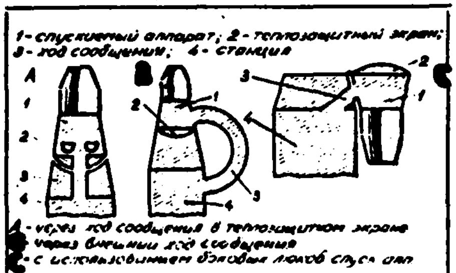
1 Межпланетный корабль Ф. Цандера.

KEY:
1 - <u>The F. Tsander Interplanetary Spaceship</u>; 2 - second stage; 3 - first stage.



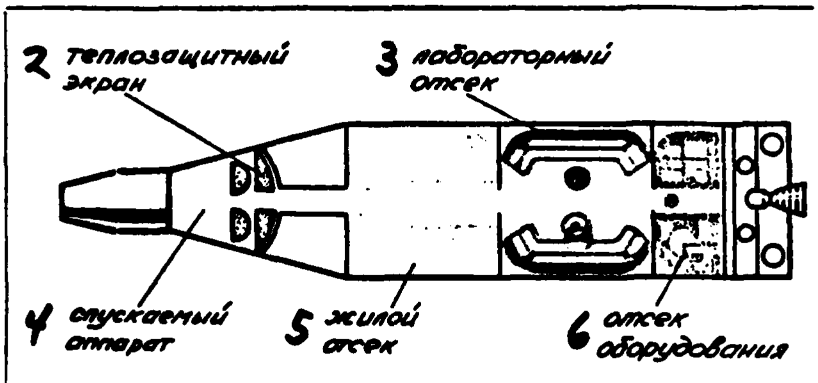
4 «Гантельная» система.

4 - <u>The "Hantel" ("Dumbbell") System</u>; 5 - orbital station; 6 - the last stage of the carrier rocket.



Способы перехода космонавтов из спускаемого аппарата в станцию. 8

8 - <u>Ways for cosmonauts to get from the descent vehicle into the space station</u>;
<u>SUBKEY</u>: 1 - descent vehicle; 2 - heat shield; 3 - connecting passage; 4 - space station.
A - via the connecting in the heat shield; B - via an external connecting passage; C - employing lateral hatches of the descent vehicle.



1 Схема орбитальной станции с экипажем из двух человек.

<u>KEY</u>: 1 - Diagram of an orbital station with a two-man crew; 2 - heat shield; 3 - laboratory compartment; 4 - descent vehicle; 5 - living (habitation) compartment; 6 - equipment compartment.

It is possible to detect certain of the elements of the Noordung space station in the present-day designs. It is only necessary to connect the habitable (living) compartments, and the laboratory and machine compartments, apparently, by a common orbital unit.

In 1930 F. Tsander prepared a report for the V International Congress on Air Communications (Transportation). Here is an extract from this report: "The establishment of interplanetary space stations near the Earth and other planets will be very important. Aircraft and rockets, which have risen from the Earth, will be able to fly to them; the aviators can also rest there after their transfer ascent.

Interplanetary journeys will become much more inexpensive due to the establishemtn of these space stations, since everything necessary for the subsequent navigation to another planet can be stored on an interplanetary station." And a year earlier the self-taught mechanic, Yuriy Kondratyuk, wrote: "The possession of a base... will give that great advantage, that during each flight we will not have to transport from the Earth into interplanetary space and back materials, tools, machines and people...

...Rockets from the Earth... will be sent only for supplying the base and for replacing after more or less prolonged time intervals one brigade of personnel with another.

...Initially on a base there should be:

1) people - a minimum of 3 persons with a chamber for them and with all the things necessary for their existence;

2) a powerful telescope...;

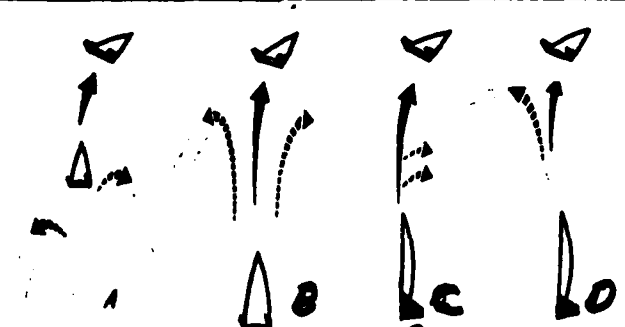
3) small rockets for 2 persons with a a fuel reserve..."

One can only be amazed at the brilliant sagacity of the pioneers in rocketry, who a half century ago were able to define and to do the ground work for the directions of the present-day operations.

A Band of Obstacles

The medical people were somewhat pessimistically disposed. In their opinion, man would be the weakest "element" in an orbital space station. Over a prolonged period of time the members of a crew would be subjected to the effects of vibration, heat, contamination of the cabin atmosphere, radiation, emotional stress and, finally, weightlessness.

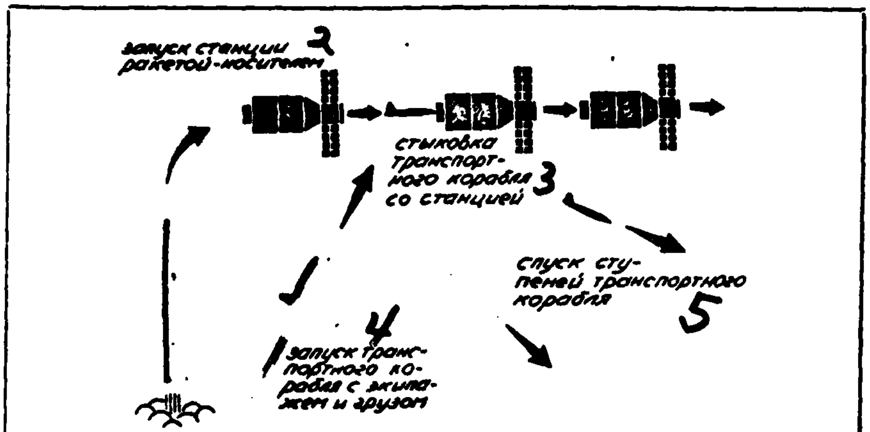
Weightlessness - it was precisely this, that the specialists in space medicine said would mainly be the straw that would break the camel"s back. As some scientists said, it was not possible to lay the foundation only on the assertion of the cosmonaut, that he felt well. Very accurate measurements were necessary for recording even the most insignificant unfavorable effect of weightlessness. For a while the specialists agreed, that a space flight with a duration of a few weeks would reflect on the health of the cosmonauts, even if artificial gravity were created on-board. Some considered, that demineralization of the bony tissue would take place as early as over a period of sixty days, which would threaten the integrity of the skeleton after the return to Earth. And, therefore, it would not be possible without artificial gravitation. The optimistic medical people saw a way out with the employment of active physical exercise by the crew.



А-с использованием ракеты-носителя; Б-с использованием сбрасываемых топл. баков; В-с использованием носителя из трех идентичных блоков; Г-с использованием параллельно расположенных неидентичных ступеней

Проекты транспортных кораблей. 1

KEY: 1 - Designs of transport craft.
A - employing a carrier rocket;
B - employing jettisonable fuel tanks;
C - employing a carrier made from three identical units;
D - employing parallelly situated non-identical stages.



Вывод на орбиту долговременной станции. 1

<u>KEY</u>:

1 - <u>The insertion of a long-term space station into orbit</u>.

2 - launch of a space station with a carrier rocket;
3 - docking of a transport craft with a space station;
4 - launch of a transport vehicle with a crew and cargo;
5 - stage descent of a transport craft;

In any case, engineers are already proposing methods for the creation of artificial gravity. The "Hantel (dumbbell) system" has appeared. A spacecraft, inserted into orbit, is connected by a long hollow cylinder with the last stage of a carrier. And this "Hantel" (dumbbell), being a hundred meters in length, is set into spinning motion. But if rotation is imparted to the entire space station, how are experiemtns to be conducted on-board, which weight only hampers? It was for their (the experiments) that it was necessary to fly into space! This means, that some part of the space station should rotate. Plans for orbital stations, equipped with centrifuges, are appearing. And this is a difficult matter - to find the free space on a space vehicle for such a device, to get everything into the assigned weight of the assigned system, to make energy for the drive. The planning of complex machines is reminiscent of a chain reation: the solution of one problem leads to the appearance of ten others, requiring great attention. Judge for yourself. The power of the energy devices of modern space vehicles is several kilowatts. On large orbital stations it can be as much as tens of kilowatts. And in this case simple, reliable solar batteries lose their advantages: their area increases in proportion to the power required. Imagine a cylinder with tremendous "burdock-like leaf-like structures" of the solar batteries. Additional per-

turbing moments of roattion manifest themselves and the braking (deceleration) of the space station is sharply intensified. It is necessary to counter these perturbations, and consequently, carry additional fuel reserves on-board. Powerful mechanisms are necessary for the deploying of the enormous solar battery panels. What are the advantages here! Specialists see a way out in the employment of nuclear power devices. But this also involves its own series of problems: the protection of the crew, and the danger of radioactive contamination of the atmosphere and the surface of the Earth, etc.

And the life-support (survival) of the cosmonauts?

There are two ways. The first is to increase the on-board supplies of oxygen and water (depending on the assigned duration of the flight).

The second way is the employment of regenerative life-support systems on-board. Calculations show: for a six-place (six-seat) orbital space station with a year's flight duration the saving in weight with oxygen regeneration is about two tons, and with regeneration of water - five tons. What is more the problem of waste removal is partly resolved. On this same six-place space station during the course of a year several tons of waste (the remains of food, paper, wash water, the products of the vital activities of man, etc.) will accumulate. Even if this "garbage" is dehydrated or incinerated, the weight of the dry residue will be more than a ton. Another, very tempting variant - is to employ the waste as fuel. A ZhRD (liquid-propellant rocket engine) with a thrust of 110 tons, operating on liquid propellant, consisting of 40 percent waste, has successfully passed tests. This promises a certain decrease in the basic fuel reserves, and moreover, ensures the operation of the engines in the case of a malfunction of the basic fuel systems.

And, finally, the number one problem: how to organize reliable transport communication with a space station?

A Space Street-Car

The space station is in orbit. It has a lifetime of several years.

But it is necessary to periodically change the personnel. And it is also necessary to exchange cargo between the space station and the Earth. More briefly - ti is necessary to organize "shuttle" operations in space. So that transport is available to the crew at any minute, it has its own space street-car.

Within specific time intervals a carrier rocket puts a spaceship into orbit. For example, one of the "Soyuz" type. In it there is either the next shift of cosmonauts or a payload. Having docked with the space station, the transport vehicle unloads, and takes on-board everything, which has to be ferried to Earth, and completes its descent. On the next flight there is a new ship and a new rocket. And what will be next, when there is a whole swarm of orbital stations hovering above the Earth? There will never be enough money for this, because the cost of a carrier and a space is estimated in multi-digit numbers. It is necessary to look for other ways.

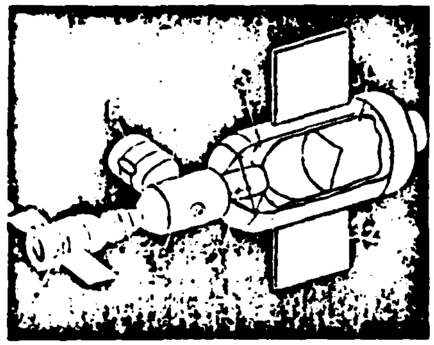
The most rational answer is to employ reusable shuttle vehicles as transport craft. In our day cosmonautics with respect to altitudes and speeds has gone far beyond aviation. Here are data of present-day aircraft: a speed of 4,000 km/h, an altitude of 40 km. Space vehicles ascend to 200 kilometers and higher, at speeds of 28,000 km/h. If aircraft could successfully conquer the interval, which today separates aviation and cosmonautics, the employment of reusable flight vehicles for transport communication in space would begin.

There are a number of plans for such vehicles. Basically they are similar to each other: two or three stages, all stages recoverable, a rocket launch from the Earth, an "aircraft" landing on the Earth.

In general, these are not new ideas. In Tsiolkovskiy's work, "A Spaceship with Vehicles preceding it" (1933) it is possible to find a description of a two-stage space system. The first stage is employed for flight in the dense layers of the atmosphere, the second - for flight in near-earth space. Tsiolkovskiy wrote: "...a semi-reactive aircraft of considerable size can carry in tow a purely reactive instrument (a spaceship) to as great an altitude as possible. Then the spaceship, left to its own resources, activates its purely reactive engine and will

soar beyond the atmosphere."

An orbital space station with an interchangeable crew.
1 - habitable (living) compartment; 2 - solar battery panels; 3 - laboratory compartment; 4 - air-lock chamber; 5 - mooring structure; 6 - unit docked to a spaceship for the carrying out of experiments; 7 - transport vehicle.

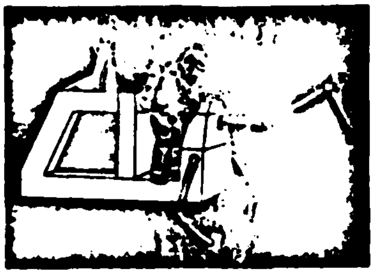


Noordung's orbital station.
1 - "habitable ("living") wheel"; 2 - laboratory; 3 - machine section.

In 1924 F. Tsander published "A Description of an Interplanetary Spaceship...". His craft was also two-staged, consiting of two aircraft type devices. A large aircraft - for ascent, a second - for flight in space and for descent. Tsander proposed employing the elements of the structure of the spent first stage as additional fuel for the second aircraft - a principle, which in our day has been adopted in the creation of carrier rockets for long-distance space flights.

Today, reusable transport craft (shuttles) are already being developed. Flight plans have been selected, the basic types of application have been formulated, and the specifications imposed on the main elements of the craft have been specified. The craft should carry out a large number of flights in space and return. The figure 100 has even been specified. These craft will be built in passenger and cargo models. The creation of transport towing craft has been specified. It would not be possible to carry out the assembly of the individual sections of orbital stations in space without them.

The appearance of transport craft in the form, in which we visualize them today, will become possible, apparently, only by the end of the seventies. Too many problems confront their creators. one of these



A platform and a capsule for assembly operations in space.

is the combatting of high heating of the design elements during the return to Earth. Certainly, there are methods of protecting one-time-use craft - for example, by covering the capsule with a layer of ablating "daubing." But in this case the preparation of the "transport" for a new flight occupies much time, and it is very expensive. Apparently, the space aviation designers will have to seek other solutions, more acceptable with respect to efficiency and expenditures. But it is doubtless: in the very near future entire systems, including orbital stations, cargo and passenger transport craft will be operating in space. A new stage is beginning in cosmonautics.

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